456 are in contact with the sloping portion of teeth 458. Vertices 459 of teeth 458 are in contact with the sloping portion of teeth 456. In response to heating of first spring 46 by a first amount of heat, pin 454 pushes pins 450 and 452 in a first direction toward the first position. Teeth 456 engage with teeth 458 and impart rotation to pin 450. The movement of pin 450 in the first direction is guided by projection 460 within the first channel 480. As projection 460 moves past the upper edge of lower guide 464, the rotation imparted to pin 450 causes projection 460 to move between lower guide 464 and upper guide 466. As spring 46 cools, pin 460 and projection 460 are urged in the second direction by second spring 44. Projection 460 slidingly engages first guiding surface 472 and is supported within first rest 468 of guide 464, as shown in FIG. 7B. Vertices 457 and 459 are again aligned with the sloping portion of the opposing teeth.

In response to heating of spring 46 by the first amount of heat, projection 460 is urged toward third guiding surface of upper guide 466. As a result of rotation imparted to pin 450 by teeth 456 of pin 454, projection 460 moves toward and is restrained by second rest 469. Upon cooling of spring 46, projection 460 is urged downward by spring 44, slides along lower guide 464, and into a second channel 480 of member 462.

Again referring to FIG. 7A, in response to heating of spring 46 by a second, greater amount of heat pin 450 and projection 460 again move in the first direction toward the first position. However, because of the greater force imparted to pin 450, projection 460 does not rotate and slide between guides 464 and 466, but rather continues past upper guide 466 to a position above the uppermost part of vertical edge 476*a*. As spring 46 cools, projection 460 is urged downward by spring 44 and slides along second guiding surface 474. Since there is no rest position along surface 474, projection 460 continues to slide and moves into the second channel 480.

Application of the second amount of heat to spring 46 when pins 452, 450, and 454 are in the first position as shown in FIG. 7B also results in movement of projection 460 from first rest 468 toward second rest 469. Upon cooling, projection 460 moves into channel 480.

The second amount of heat and increased level of spring force from spring 46 is thus able to permit a general resetting of pins 452 to a channel 480. Regardless of whether the projection is within a channel or being supported in the first position, application of the second amount of heat results in movement of projection 460 in a channel 480. This is useful for assemblies controlled by a processor. With other types of supporting mechanisms described herein, a reset of a pin to the downward position is accomplished by a second actuation if the pin is already in the first position. When controlled by a processor, the processor should thus remember the position of a pin in order to determine whether or not an actuation signal is required. In the embodiment of reset mechanism shown in FIGS. 7A and 7B, the processor need not remember the position of the pins, and may apply the second amount of heat to effect a reset. Thus, processor controlled operation of a braille display, for example, requires less processor memory and time. The variable springs described herein, some of which are depicted in FIGS. 10–13, are especially useful with the supporting mechanism described above and depicted in FIGS. 7A–7B. The first amount of heat is applied to one portion of the spring, resulting in a first spring force sufficient to push projection 460 onto guiding surface 472. The second amount of heat includes heating both portion of the variable spring, resulting in a second spring force sufficient to push projection 460 onto guiding surface 474.

Although various embodiments of supporting mechanisms have been described herein, those of ordinary skill in the art will recognize many equivalents to these supporting mechanisms that are also useful in the present invention. Also, those of ordinary skill in the art will recognize various ways in which to incorporate stops in the various supporting mechanisms to limit the upward or downward travel of the pins.

The use of the various embodiments of supporting mechanisms permit continued support of pin 34 or 434 in the upward position without need for continued heating of spring 46, and also permits pin 34 or 434 to resist larger axial loads that could otherwise be supported by spring 46. Axial loads along pin 34 or 434 can be transmitted into midplate 26 by use of this supporting mechanism. The ability to support higher axial loads enhances the ability of pins 34 or 434 to emboss a surface presented to the top side of top plate 22.

FIG. 8 depicts diagrammatically an alternate heating element useful with the present invention. Thermoelectric element 500 is shown schematically in a side view. Thermoelectric heaters (and coolers) utilize the Peltier effect to act as a solid-state heat pump with no moving parts or fluid reservoir. The Peltier effect is a physical phenomenon that occurs between a semiconductor junction of a p-type semiconductor 502 and an n-type semiconductor 504. When current flows across the junction, electrons travel from the low-energy state in the n-type semiconductor to the high-energy state in the p-type semiconductor. This requires energy, which is absorbed from the surroundings, making a cool surface at the junction. Reversing the current makes the junction get hot. Typically, bismuth telluride junctions are placed as in FIG. 21 to create cold and hot surfaces. Thermoelectric elements 500 such as in FIG. 21 are commercially available in sizes as small as 1.8 mm×3.4 mm, including by way of example only the OptoTEC (TM) brand thermoelectric module assemblies, which are useful in a braille-cell matrix or shaped memory spring actuator as shown in FIG. 8.

As shown on the left side of FIG. 8, a pin 34 is shown in the 34*a* first position. Pin 34 is in the first position in response to heating of memory spring 46 by thermal conductor 510*a* of thermoelectric heater 500'. Heater 500' is being supplied with power from interface controller 512 such that thermal conductor 510*a* is hot and thermal conductor 510*b* is cool. Although spring 46 may be permitted to cool by removing power to thermoelectric heater 500', it is also possible to actively cool memory spring 46. Pin 34 shown on the right side of FIG. 8 is shown in the 34*b* downward position after spring 46 has been actively cooled by thermoelectric heater 500. Control circuitry 512 includes a polarity inverter that permits a reversing of electrical polarity to lead wires 503 such that thermal conductor 510*a* of heater 500 is actively cooled, rejecting heat to thermal conductor 510*b*. One advantage of this technique is that by simply reversing the polarity of the thermoelectric heater 500, one can actively cool the spring as well, thus reducing the lag time to allow the spring and pin to return to the un-actuated state.

The present invention contemplates heating memory spring 46 either by resistive heating or by thermoelectric heating. In one embodiment of the present invention, the resistive process used 12 V and 0.5 A over 0.2 sec in order to actuate the spring. This input produced a power of P=VI=6 W, and thus work W=Pt=1.2 J. In an embodiment of the present invention utilizing thermoelectric heating, the same actuation can be achieved with 0.5 V and 0.2 A. This